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# Antenna Array Synthesis for Suppressed Side Lobe Level Using Combination of Global and Local Search

Žarko Rosić
University of Belgrade, Faculty of Organization Sciences, Jove Ilića 153, Belgrade, Serbia

***Abstract* — This paper presents an optimization method for the synthesis of linear antenna array with nonuniform amplitude. Combination of global and local search is applied to optimize excitation amplitudes for suppressing side lobe level. Optimization is done using MATLAB. Results demonstrate that the proposed methods outperform the previously published method.**

***Key words* —Array Factor, Global and Local Search, Linear Antenna Array, Side Lobe Level.**

## I. INTRODUCTION

Multiple identical antennas can be arranged in space and interconnected to produce directional radiation pattern. Such a configuration is referred to as an antenna array, or simply an array. Several small antennas can be interconnected to provide the same performance as one large antenna. Some of the biggest disadvantages of single antenna radiation pattern is low directivity (gain) and relatively wide radiation pattern. Antenna arrays are widely used in wireless, satellite, mobile and radar communication systems (see [1], [3], [5]). Communication system performance depends on the design of the antenna array. The system needs to have low side lobe level (SLL) in order to avoid interference with other systems operating in the same frequency band and to have high power gain in the given direction. The radiation pattern of the antenna array depends on physical placement of antenna elements, amplitude and phase of excitation. Methods used for the antenna array synthesis can be classified in two categories: deterministic (see for example [1]-[3], [5]-[7]) and stochastic (see for example [8]-[18]). The disadvantage of deterministic methods is that they find a global minimum only after an exhaustive search over the feasible region. Stochastic methods can almost all be proven to find a global minimum with asymptotic convergence in probability. Some of the methods used for the antenna array synthesis are: Genetic Algorithms (see [8], [14]-[16]), Invasive Weed Optimization (IWO) (see [9]), Particle Swarm Optimization (PSO) (see [10]), Evolutionary Algorithms (EA) (see [11], [17]), Nature-inspired Cuckoo Search (CS) (see [12]) and Tabu Search (see [8], [18]). In this paper we will be using combination of local and global search to find optimal excitation amplitudes of the antenna array for the minimum side lobe level. Results of this method will be compared to the Evolutionary Algorithms (EA) from [11]. In all cases the proposed method produces better performance than the Evolutionary Algorithms (EA) from [11].

## II. LINEAR ANTENNA ARRAY WITH UNIFORM SPACING

The antenna array radiation pattern may be found according to the pattern multiplication theorem (see, for example, Ch. 6 from [1], [2] and Ch. 3 from [5])

$$Array\ \ pattern = Array\ \ element\ \ pattern\ X\ \ Array\ \ factor \quad (1)$$

*Array element pattern* – the pattern of the individual elements,
*Array factor (AF)* – a function dependent on the physical placement of antenna elements, amplitude and phase of excitation.

If we replace each element of the antenna array with an isotopic point source the resulting pattern is the array factor. In this paper we will use the 2N element linear antenna array with uniform spacing and nonuniform amplitude as shown in Fig. 1. Space between elements is $\frac{\lambda}{2}$ where $\lambda$ is the wave length.

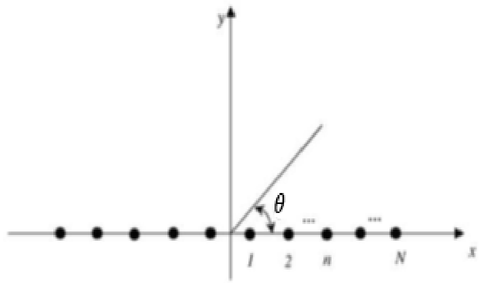


**Fig 1. Geometry of the 2N element linear antenna array with uniform spacing**

The array factor (see [1], [2], [3], [5]) for linear antenna array (as shown in Fig. 1) is

$$AF(\theta) = 2\sum_{n=1}^{N} a_n \cos\left[\frac{(2n-1)}{2} kd\cos(\theta)\right] \quad (2)$$

Where:
$a_n$ - Excitation coefficient
$d$ - Distance between the elements
$k$ - Wave number $\frac{2\pi}{\lambda}$
$\theta$ - Angle between the line of observer and the source position.

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Normalized array factor is given by Equation (3)

$$(AF(\theta))_{norm} = \frac{|AF(\theta)|}{|\max(AF(\theta))|} \quad (3)$$

In the field of telecommunication the decibel (dB) is often used as a unit of measurement (see [4]).

The voltage gain of antenna array in dB is given by Equation (4).

$$(AF(\theta))_{norm} = 20\log\frac{|AF(\theta)|}{|\max(AF(\theta))|} \quad (4)$$

## III. PROBLEM FORMULATION

In the antenna array synthesis it is often more desirable to achieve minimum side lobe level than narrow beam. To achieve the desired radiation pattern with minimum side lobe level we need to find the optimal excitation coefficient $a = (a_1, a_2, ..., a_N)$. For the cost function the following expression was used:

$$Cost = 20\log\frac{|AF(\theta)|}{|\max(AF(\theta))|} \quad (5)$$

The excitation coefficient $a$ satisfies the conditions: $a_n \in [0.1],\ n \in \{1,\dots,N\}$.

## IV. ALGORITHM

Our approach uses a combination of global search with respect to $\theta$ and local search with respect to $a$. The global search is performed using multistart local search with MATLAB software package (R2014a) for local search. The best local solution was not used as a solution for the global search, because it belongs to the maximum of the main lobe. Instead, the second best solution that belongs to the maximum SLL was used. In the main algorithm loop the local search with respect to $a$ was used on a small region with fixed $\theta$ found by the global search. The local search with respect to $a$ was performed using the existing function "fmincon" from MATLAB software package (R2014a), on a small neighborhood of the current point $a^k$. Lower and upper bounds for each coordinate of vector $a$ are defined using the following expression:

$$LOW_i = \left[a_i^k - R\right],\ i \in N \quad (6)$$

$$UP_i = \left[a_i^k + R\right],\quad i \in N$$

The algorithm is given bellow:

1. Choose an initial solution $a^1$, R and $k \leftarrow 1$
2. *Global search for* $\theta$. Perform the global search for $\theta$ with fixed $a^1$ to locate the maximum side lobe level (SLL) $\theta^1$ for the current solution.
3. Set $F^* = F(a^1, \theta^1)$, $a^* = a^1$, $\theta^* = \theta^1$
4. Repeat until $k > k_{\max}$
   a) *Local search for* $a$. Perform the local search for $a$ on the small region with fixed $\theta^k$. Solution of the search is $a^{k+1}$.
   b) *Global search for* $\theta$. Perform the global search for $\theta$ with fixes $a^{k+1}$ to locate the maximum side lobe level (SLL) $\theta^{k+1}$ for the current solution.
   c) If the cost function for the current solution is better than $F^*$ then set $F^* = F(a^{k+1}, \theta^{k+1})$, $a^* = a^{k+1}$, $\theta^* = \theta^{k+1}$.
   d) If there is no improvement of the solution $F^*$ after a given number of iterations than stop the loop.
   e) $k \leftarrow k+1$
5. Outputs of the algorithm are $F^*$, $a^*$, $\theta^*$.

Experiments were performed for $R = 0.005$, $0.002$ and $0.001$. The observed results were better when $R$ is lower. In this paper value of $R = 0.001$ was used.

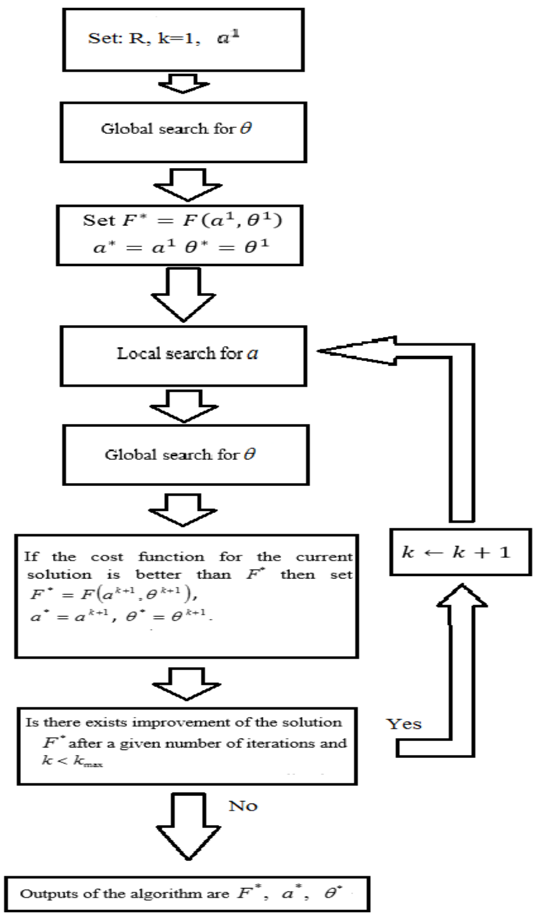


**Fig 2. Flow chart**

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## V. RESULTS

All computations were performed using MATLAB software on PC Intel I3 Processor 3.5GHz and 8 GB RAM. The stopping condition for the loop was 300 iterations. Algorithm was used to find the optimal excitation for 16, 24, 32 array elements for the minimum side lobe level (SLL). Tables 1, 2, 3 shows SLL and the excitation coefficient from [11] and SLL and the excitation coefficient found with the algorithm presented in this paper. The radiation pattern for each set of elements is shown in Fig. 3, 4 and 5.

**Table 1. Excitation coefficients of 16 elements antenna array**

| El. No. | EA [11] | GLO (obtained results) |
|---|---|---|
| ±1 | 1.0000 | 1.0000 |
| ±2 | 0.9216 | 0.9216 |
| ±3 | 0.7843 | 0.7803 |
| ±4 | 0.6000 | 0.6030 |
| ±5 | 0.4078 | 0.4190 |
| ±6 | 0.2471 | 0.2572 |
| ±7 | 0.1255 | 0.1333 |
| ±8 | 0.0588 | 0.0572 |
| **SLL in dB** | **-44.6710** | **-47.9859** |

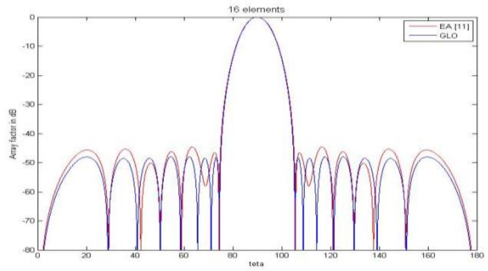


**Fig 3. Array factor for 16 elements**

**Table 2. Excitation coefficients of 24-elements antenna array**

| El. No. | EA [11] | GLO (obtained results) |
|---|---|---|
| ±1 | 0.9098 | 1.0000 |
| ±2 | 0.8667 | 0.9560 |
| ±3 | 0.7608 | 0.8809 |
| ±4 | 0.6667 | 0.7708 |
| ±5 | 05333 | 0.6468 |
| ±6 | 0.4431 | 0.5134 |
| ±7 | 0.3020 | 0.3851 |
| ±8 | 0.2196 | 0.2740 |
| ±9 | 0.1725 | 0.1769 |
| ±10 | 0.0941 | 0.1051 |
| ±11 | 0.0431 | 0.0554 |
| ±12 | 0.0235 | 0.0229 |
| **SLL in dB** | **-40.9400** | **-54.3729** |

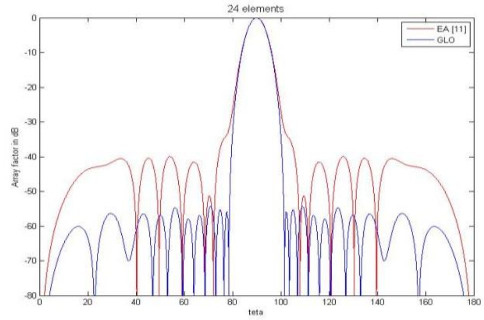


**Fig 4. Array factor for 24 elements**

**Table 3. Excitation coefficients of 32-elements antenna array**

| El. No. | EA [11] | GLO (obtained results) |
|---|---|---|
| ±1 | 0.9608 | 0.9590 |
| ±2 | 0.9412 | 0.9370 |
| ±3 | 0.9137 | 0.8953 |
| ±4 | 0.8824 | 0.8339 |
| ±5 | 0.7961 | 0.7573 |
| ±6 | 0.7725 | 0.6715 |
| ±7 | 0.6157 | 0.5818 |
| ±8 | 0.5882 | 0.4860 |
| ±9 | 0.4941 | 0.3943 |
| ±10 | 0.4392 | 0.3124 |
| ±11 | 0.3333 | 0.2343 |
| ±12 | 0.2392 | 0.1682 |
| ±13 | 0.2353 | 0.1160 |
| ±14 | 0.2000 | 0.0766 |
| ±15 | 0.1255 | 0.0426 |
| ±16 | 0.0980 | 0.0272 |
| **SLL in dB** | **-35.06** | **-53.9804** |

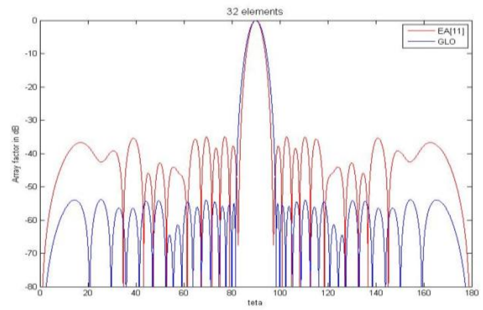


**Fig 5. Array factor for 32 elements**

In all three cases the proposed algorithm gives better results than the algorithm from [11]. The side lobe level is $< -47dB$ compared to the main lobe which is highly desirable.

## VI. CONCLUSION

The paper proposes a new algorithm for finding the optimal excitation amplitudes of the antenna array which minimize side lobe level. The algorithm is used to find the optimal excitation for 16, 24 and 32 array elements for the minimum side lobe level and the results are compared to the results of the Evolutionary Algorithm presented in [11]. In all three cases the proposed algorithm outperforms the Evolutionary Algorithm and shows a good potential for the antenna array synthesis.

## VII. ACKNOWLEDGEMENT

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## REFERENCES

[1] C. A. Balanis, "Antenna Theory: Analysis and Design," John Wiley & Sons, 1997.

[2] W. H. Kummer, "Basic array theory," Proceedings of the IEEE, Vol. 80. No. 1, January 1992.

[3] R.S. Eliot, "Antenna Theory and Design," Prentice Hall, New Jersey, 1981.

[4] Z. Tripovski, "Osnovi Telekomunikacija," Delta press, Novi Sad, 2004

[5] W. L. Stutzman and G. A. Thiele, "Antenna Theory and Design", Wiley, New York, 1998.

[6] S. Schelkuno, "A mathematical theory of linear arrays," Bell Systems Technology Journal, Vol. 22, No. 1, 80-107, 1943.

[7] John D. Kraus, "Antennas," McGraw-Hill, New York, 1988.

[8] Y. Cengiz, H. Tokat, "Linear antenna array design with use of genetic, memetic and tabu search optimization algorithms," Progress in Electromagnetics Research C, Vol. 1, 63-72, 2008.

[9] L. Pappula, D. Ghosh, "Constraint-based synthesis of linear antenna array using modified invasive weed optimization," Progress in Electromagnetics Research M, Vol. 36, 9-22, 2014.

[10] M. Khodier, M. Al-Aqeel, "Linear and circular array optimization: A study using Particle Swarm Intelligence," Progress in Electromagnetics Research B, Vol. 15, 347-373, 2009.

[11] Ch. Ramesh, P. Mallikarjuna Rao, "Antenna array synthesis for suppressed side lobe level using evolutionary algorithms," International Journal of Engineering and Innovative Technology (IJEIT), Vol. 2, 2012.

[12] K. Abdul Rani, M. Abd Malek, N. Siew-chin, "Nature-inspired cuckoo search algorithm for side lobe suppression in a symmetric linear antenna Array," Radio engineering, Vol. 21, 2012.

[13] A. Sharma, K. Cecil, "Optimization of linear antenna array using big bang algorithm for reduction in side lobe levels," International Journal of Engineering and Innovative Technology (IJEIT), Vol. 3, 2014.

[14] S. Shrivastava, K. Cecil, "Performance analysis of linear antenna array using genetic algorithm," International Journal of Engineering and Innovative Technology (IJEIT), Vol. 2, Issue 5, November 2012.

[15] G. K. Mahanti, N. Pathak, P. Mahanti, "Synthesis of thinned linear antenna arrays with fixed side lobe level using real-coded genetic algorithm," Progress In Electromagnetics Research, PIER 75, 319-328, 2007.

[16] A. Monorchio, S. Genovesi, U. Serra, A. Brizzi, G. Manara "A technique to optimize nonuniformly spaced arrays with low side lobe level by using a genetic algorithm," Antennas and Propagation Society International Symposium, 2005 IEEE; 08/2005.

[17] P. Wani, O. P. Acharya, "Pattern synthesis for linear antenna array using characteristics evolution optimization," IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 9, Issue 3, 2014.

[18] K. Guney and A. Akdaglı, "Null steering of linear antenna arrays using a modified tabu search algorithm," Progress In Electromagnetics Research, PIER 33, 167–182, 2001.

## AUTHOR'S PROFILE

**Žarko Rosić** received the MSc in electrical engineering and computer science from University of Belgrade in 2012. He is a graduate student at Faculty of Organization Sciences from University of Belgrade, Department of Operational research. His current research interests are antenna arrays, mathematical optimization and electromagnetic wave.